Cycle Time Reduction in Injection Moulding Through Various Techniques with Thermal Analysis

Kailas R.Dudhe

Dept.of Mechanical Engineering, Government College of Engineering, Amravati

Abstract- **cycle time of a part in injection molding process is very importantas the rate of production and quality of the products manufactured depends on it. Cycle time is the total time from beginning to the end of the process. Cycle time includes process time. During which a unit is acted upon to bring it closer to an output, and delay time, during which a unit of work is spend waiting to take the next action.Decreasing the cycle time of a process increases the manufacturing capability in both quality and quantity.This can be achieved through various techniques like external cooling, improve capacity of cooling tower, Install Flow Meters, Proper design of the cooling channel, Optimization Of Injection Molding Machine Parameters like Cooling Time, Back Pressure And Plasticizing Limit, Optimum Height for Counter Flow Cooling Tower.Any manufacturing activity would like to have optimized productivity and quality. In injection moulding of plastics, if quality is taken care of by part design, mould design and mould precision, then productivity is also ensured on account of zero defect moulding without rejection and optimised cycle time.Cycle-time optimization starts at design stage. Cooling time takes up over 50% of cycle time. Therefore understanding of cooling in the mould becomes very important.**

Index Terms- **cycle time, Injection Molding Machine Parameters, mould design, cooling tower.**

I. INTRODUCTION

Injection moulding is a popular manufacturing method and mostly applied for producing plastic parts. The process of manufacturing parts is molten plastic material is injected into the injection mould it is generally three phase process (i)Filling (ii) Packing (iii) Cooling (iv)Ejection by all these process cooling stage is very important one because it effects on molding of part quality. In operation of molding cycle 70 to 80% takes cooling stage by selecting suitable cooling channels design can reduce cooling time and increase the production of the molding process[1].

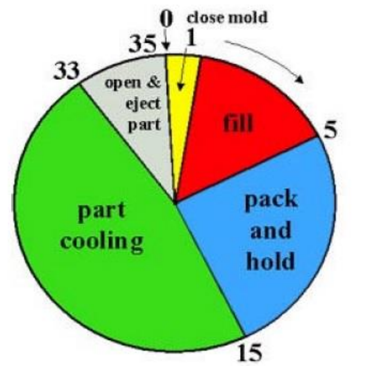
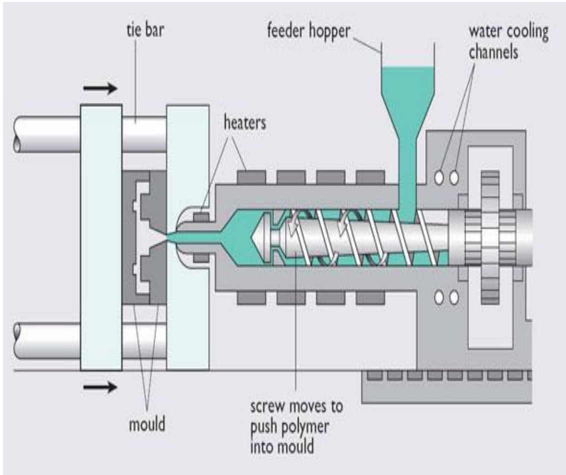
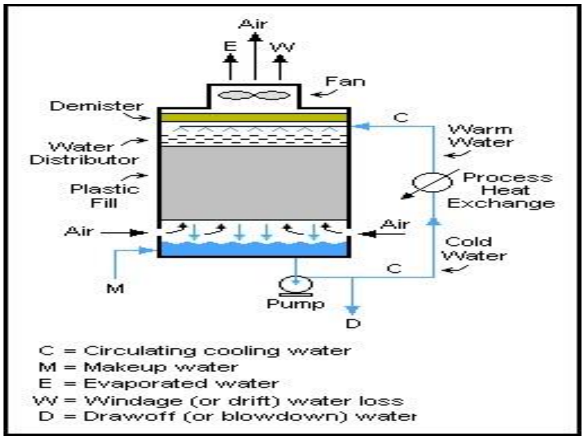
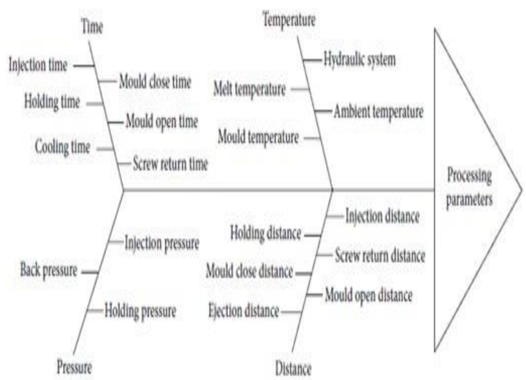


Figure 1. Typical injection molding cycle clock

Design of efficient cooling channels which can achieve a uniform cooling and reduce the defectsof the molded part.The usage of plastics is mainly lower weight and melting temperature, compared to other materials like metals. The usage of plastic is more in all the areas because of compact designs possible with complex geometries[2].the processing parameters involved in injection moulding operation is shown in figure 1.







II. CHALLENGES

Here are the challenges faced by injection molding process, 1) more cycle time is given to production than real cycle time , 2) Flow lines are streaks, patterns, or lines, 3) Sink Marks, 4) Warping, 4) Vacuum voids are pockets of air trapped within or close to the surface of an injection molded prototype, and 5) cooling tower efficiency . Finally, to Manipulate cooling time, back pressure, and plasticizing limit on the injection molding machine to reduce the cycle time and keep the quality of the part that deal with problems such as shrinkage, flash, and other abnormalities

.

III. METHODOLOGY

There are some methods to reduce cycle time and improve production rate.

A. Proper design of the cooling channel

B. Improve Cooling Tower Efficiency

C. Optimization Of Injection Molding Machine Parameters

A. Proper design of the cooling channel

Proper design of the cooling channel is required for a faster cooling phase. Historically, the cooling channels have been created by drilling several straight holes (cooling channels) inside the mold core and cavity. Such type of cooling channels is called as "Conventional Cooling Channels (CCC)." However the cooling process in CCC is too long because of non uniform cooling of part. If the part's temperature can be reduced more quickly and uniformly, it will shorten the cooling time without compromising on part quality because nearly uniform temperatures can be held in part by using conformal cooling.

❖ *Physical and mathematical modelling of cooling process*

In the physical sense, cooling process in injection molding is a complex heat transfer problem. The objective of mold cooling analysis is to find the temperature distribution in the molded part and mold cavity surface during cooling stage.

The general heat conduction involving transition heat transfer problem is governed by the partial differential equation. The cycle-averaged temperature distribution can be represented by the steady-state Laplace heat conduction equation. When the heat balance is established, the heat flux supplied to the mold and the heat flux removed from the mold must be in equilibrium. The heat balance is expressed by equation:

$$\dot{Q}m + \dot{Q}c + \dot{Q}e = 0 \qquad (1)$$

where $\dot{Q}_m$, $\dot{Q}c$ and $\dot{Q}e$ are the heat flux from the melt, the heat flux exchange with coolant and environmentrespectively.By neglecting the heat lost to the surrounded environment, the equation of energy balance can be simplified as

$$\dot{Q}m + \dot{Q}c = 0 \qquad (1)$$

The heat flux transferred into the coolant from the molten plastic can be calculated as

$$Q_m = 10^{-3}\left[(T_M - T_E)C_p\right]\rho_m \frac{s}{2} x \qquad (3)$$

Where T_M is the melt temperature, T_E is the ejection temperature, C_P is the specific heat of the plastic material, ρ_m is the melt density, s is the part thickness, and x is the pitch of the cooling channels.

The cooling time t_c, which is the time of heat flux from the mold exchanges with coolant, is expressed as

$$Q_c = 10^{-3} t_c \left(\frac{1}{10^{-3}\alpha\pi d} + \frac{1}{k_{st}S_e}\right)^{-1}(T_W - T_C) \quad (4)$$

Where α is the heat transfer coefficient of water, k_{st} is the thermal conductivity of the mold steel, T_W is the mold temperature, and T_C is the coolant temperature.

The effect of the cooling channels position on the heat conduction is considered by applying shape factor, S_e

The cooling time of the molded part in the form of plate is calculated as

$$t_c = \frac{[C_p(T_M - T_E)]\rho_m \frac{s}{2} x}{T_W - T_c}\left\{\frac{1}{2\pi k_{st}}\ln\left[\frac{2x\sinh\left(2\pi\frac{y}{x}\right)}{\pi d}\right] + \frac{1}{0.03139\pi R_e^{0.8}}\right\} \quad (5)$$

It is important to understand the reaction of thermal behavior physically and mathematically in injection mold. The cooling time of the molded part in Eq. (5) shows that the cooling channels configuration does not directly affect the cooling time. However, it affects the mold surface temperature, indirectly affecting the cooling time.

B. Improve Cooling Tower Efficiency

a. Follow manufacturer's recommended clearances around cooling towers and relocate or modify structures that interfere with the air intake or exhaust.
b. Optimize cooling tower fan blade angle on a seasonal and/or load basis.
c. Correct excessive and/or uneven fan blade tip clearance and poor fan balance.
d. On old counter-flow cooling towers, replace old spray type nozzles with new square spray ABS practically non-clogging nozzles.
e. Install new nozzles to obtain a more uniform water pattern

C. Optimization Of Injection Molding Machine Parameters

The objective of this experiment is to provide statistical evidence for optimizing parameters of an injection molding machine. The machine parameters to be investigated include

1. Cooling Time,
2. Back Pressure, And
3. Plasticizing Limit.

These parameters are evaluated against the problem of decreasing the cycle time for each part.

There were three replications of each run and the cycle times were averaged. When the runs for the experiment were recorded, a statistical analysis was done to conclude evidence on the data that there were some main effects and interactions

The high and low levels for cooling time was 5 and 15 seconds, plasticizing limit was 70 and 88 mm, and back pressure was set at 5 and 17 bar.

IV. CONCLUSIONS

1. Finally by using the proposed design cycle time is improved and heat uniformly is increased compared with SDCC. An advanced method of rapid tooling is optional of injection molding for conformal cooling channel. In this study proposed conformal cooling channel design method used MPI further process.
2. By improving efficiency of cooling tower, cycle time can be reduced and increasing the production rate.
3. By Selection of Robust Cooling Channel reduces cycle time. stability and profitability of the firm.
4. Optimization Of Injection Molding Machine Parameters like Cooling Time, Back Pressure, And Plasticizing Limit reduces cycle time.

REFERENCES

[1] Krishna S. Vishwakarma1, Arpit S. Bhoyar "Study the factors on which efficiency of cooling tower can be critically acclaimed (A case Study)" ISSN : 2248-9622, Vol. 5, Issue 4, (Part -3) April 2015, pp.73-79

[2] Au, K. M. ; Yu, K. M. (2007): "A scaffolding architecture for conformal cooling design in rapid plastic injection molding", The International Journal of Advanced Manufacturing Technology, vol. 34, no. 5, pp. 496-515.

[3] Dimla, D. E.; Camilotto, M.; Miani, F. (2005): Design and optimisation of conformal cooling channels in injection molding tools, Journal of Materials Processing Technology,vol.164-165, pp.1294-1300

[4] G.L. Wang, G.Q. Zhao, H.P. Li, Y.J. Guan, "Research on optimization design of the heating/cooling channels for rapid heat cycle molding based on response surface methodology and constrained particle swarm optimization", Expert Syst. Appl. 38 (6) (2011) 6705–6719

[5] Mahesh S. Shinde,andKishor M. Ashtankar, "Cycle Time Reduction in Injection Molding by Using Milled Groove Conformal Cooling" Department of Mechanical Engineering, Visvesvaraya National Institute of Technology, Nagpur- 440010, I ndia CMC, vol.53, no.3, pp.207-217, 2017

[6] Tom Kimerling, "Injection molding cooling time Reduction and thermal stress Analysis" University of Massachusetts, Amherst MIE 605 Finite Element Analysis Spring 2002

[7] James Henderson, Aaron K. Ball, James Z. Zhang, "Cycle Time Reduction for Optimization Of Injection Molding Machine Parameters for Process Improvement" Session: ENT 105-039 2006 IJME – Intertech Conference Kimmel School of Construction Management, Engineering, and Technology Western Carolina University, Cullowhee, North Carolina, 28723

[8] Venkatesh G*, Ravi Kumar Y, Raghavendra G, "Comparison of Straight Line to Conformal Cooling Channel in Injection Molding" Department of Mechanical Engineering, National Institute of Technology Warangal, Telangana – 506004, 5th International Conference of Materials Processing and Characterization (ICMPC 2016)

[9] Xiaorong Xu, Emanuel Sachs, Samuel Allen, Michael Cima 'Designing conformal cooling channels for tooling" MIT Cambridge, MA 021